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Technical Report

HARBOR SCREENING TESTS OF MARINE BORER INHIBITORS — VI

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U. S. NAVAL CIVIL ENGINEERING LABORATORY

Port Hueneme, California

HARBOR SCREENING TESTS OF MARINE BORER INHIBITORS – VI

Y-R005-07-01-007

Type C

by

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ABSTRACT

The Laboratory is exposing wood panels impregnated with various materials to determine their resistance to attack by marine borers. This report lists the results of harbor tests of treated panels removed from exposure between 15 August 1962 and 15 August 1963. It also lists all treated panels which have been exposed for 1 year or more and which have shown no attack or insufficient attack to warrant removal.

When impregnated into wood test panels, creosote and 70-30 creosote - coal tar solution are quite effective against Martesia and teredine attack but not Limnoria attack. Copper salts, chelates, some copper complexes, and mercury salts are effective against Limnoria attack at Port Hueneme and to a lesser extent at Pearl Harbor but are ineffective against teredine and Martesia attack. Organomercury compounds are effective against Limnoria but not against Martesia or teredine borers. Tributyltin compounds are effective against Limnoria and teredine borers at Port Hueneme but have shown attack by Limnoria at Pearl Harbor. However, at Pearl Harbor they are effective against Martesia and teredine borers. Copper naphthenate (6%) and solubilized copper oxinate (containing 4% copper) are superior to creosote or creosote - coal tar in tests to date at both test sites. Phenanthrene, chloro-o-phenylphenol, and ether-soluble alkaloids of greenheart failed in a short time because of heavy Limnoria attack.

Certain organic, metal-organic, and inorganic compounds, when combined with creosote or creosote - coal tar solutions, show promise in improving the preservative ability of these materials. Aluminum oxinate and malachite green oxalate are not effective additives. Certain treatments containing a combination of one material specifically toxic to Limnoria and another material specifically toxic to teredine borers are also showing promise as preservative systems. Other systems of this type have experienced Limnoria and Martesia attack.

The tropical woods antidesma pulvinatum, greenheart, and lignum vitae are performing well at Port Hueneme. Afambeau, greenheart, and lignum vitae failed at Pearl Harbor chiefly because of Martesia attack.

Those treatments or woods which have not been attacked by one or more species during their entire period of exposure or as of 15 August 1963 are summarized.

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The Laboratory invites comment on this report, particularly on the results obtained by those who have applied the information.

FOREWORD

This is the fifteenth in a series of reports[1-14] on studies conducted by the Laboratory to develop more effective methods and materials for preservation of wooden structures exposed to the attack of marine boring organisms.

It is the sixth of a series of reports on the results of harbor exposure of treated and untreated test panels which are exposed until there is heavy Limnoria attack or until the panel is weakened by Martesia or teredine attack. Some results which have been reported previously[6, 7, 9, 10, 12] are included in this report for the purpose of comparison.

INTRODUCTION

The destructive action of marine boring organisms on structures submerged in sea water presents a major maintenance problem to Navy shore installations. The replacement of wood piling destroyed by these organisms is a costly operation, and, in addition, may remove the pier from operation during the construction period.

Under Project Y-R005-07-01-007, the Chief, Bureau of Yards and Docks, requested the Laboratory to investigate methods and materials for reducing or preventing borer attack on wooden marine structures of the Naval Shore Establishment.

One phase of this study is the impregnation of wood panels with toxic materials and the exposure of these treated panels to marine borers in harbors. The treating materials are chosen on the basis of their toxicity to marine borers as determined by the Toxicity Testing Procedure developed at this Laboratory.[8, 11] The exposure of small treated panels provides a system for rapidly screening large numbers of potentially useful treatments. The panels can be treated by ordinary laboratory equipment, require relatively small quantities of treating materials, and a large number of treatments can be exposed in a relatively small dock area. Also, the surface-to-volume ratio of these panels is so high that the rate of leaching of the preservative by the sea water is much higher than it would be for round piling sections. This small-panel screening procedure is further accelerated by exposing the more promising treatments in Pearl Harbor where, because of high water temperature and greater numbers and kinds of borers, attack begins after exposure in a half to a fourth the time required for initial attack at Port Hueneme. The exposure of full-sized piles would provide a more accurate evaluation of a preservative treatment, but the use of this method in a preliminary screening would be uneconomical.

PROCEDURE

Treatment

Treating solutions are made up on a volume percent basis for liquids and a weight percent basis for solids. With the exception of coal tar, creosote, creosote - coal tar solutions, and copper naphthenate solution, only inert solvents are used to make up solutions to 100 percent. In general, these inert solvents are xylene for nonpolar compounds, water for polar compounds, and cellosolve for combinations of polar and nonpolar compounds.

Unless otherwise noted, southern yellow pine panels are used in this study. Sets of ten panels are tagged, weighed, impregnated by the vacuum method, weighed again to determine the amount of preservative retention, and then air-dried to remove any inert solvent present. Details of the procedure are described in Reference 6. Several sets of pressure-treated ponderosa pine samples submitted by the U. S. Forest Products Laboratory, Madison, Wisconsin, and panels submitted by the Bureau of Yards and Docks are also evaluated.

Exposure and Evaluation

The panels are mounted on single or double monel or glass-reinforced epoxy racks which are suspended horizontally in the harbor about 3 feet above the mud line by nylon parachute cords. At Port Hueneme, the racks are removed twice monthly for cleaning the panels. Panels are inspected and rated twice monthly during their first year of exposure, and monthly thereafter. They are removed whenever structural failure due to borer damage is imminent. At Pearl Harbor, the panels are cleaned and inspected monthly, removed whenever extensive damage is noted, and returned to the Laboratory for evaluation.

The extent of Limnoria and Martesia attack can be readily determined by inspection of the surface of the panel. In its early stages, teredine attack is very difficult to detect by surface inspection. Consequently, in October 1963, X-ray photographs were made of all panels under test at Port Hueneme. Information on those panels attacked by teredine borers as determined by X-ray techniques is included in the appropriate tables in this report. When teredine attack reaches an advanced stage, the panel loses much of its structural strength and can easily be bent or snapped in two. All panels which are removed from exposure test are sawed in two to show the amount of teredine damage. Damage is assessed as follows:

0 = none

T = trace

VL = very light

L = light

M = moderate

H = heavy

VH = very heavy

Limnoria, Martesia, and teredine damage are always rated separately. Although individual records are kept for each panel which has been treated and exposed, the tabular data presented in this report represent average data for all panels of a given treatment exposed at the location specified.

EVALUATION OF TREATMENTS

This report deals with all treated and untreated panels which have been removed from exposure between 15 August 1962 and 15 August 1963 and with all panels still under test on 15 August 1963. The tables of data follow the main text. Panels which have not been attacked during their entire period of exposure or as of 15 August 1963 are summarized in the Appendix.

1. Creosote and Creosote - Coal Tar Solutions (Table I): Panels treated with large quantities of creosote or creosote - coal tar solutions resist Martesia and teredine attack but not Limnoria attack. The data continue to show that creosote and 70-30 creosote - coal tar solution are approximately equal in preservative ability. X-ray photographs of panels under test revealed trace to very light teredine attack on those exposed more than 4 years.

2. Inorganic Compounds (Table II): In general, copper salts, chelates, and complexes prevent Limnoria attack for considerable periods of time at Port Hueneme. Those failures which have occurred are the result of teredine attack. Teredine attack on some panels still under test was revealed by X-ray photographs. At Pearl Harbor these compounds are ineffective against both Martesia and teredine attack. At Port Hueneme and Pearl Harbor, copper naphthenate (6%) and solubilized copper oxinate (containing 4% copper) are continuing to provide better protection against all types of borers than either creosote or 70-30 creosote - coal tar solution.

Mercury salts also are effective against Limnoria, but failed in a shorter time than copper salts because of Martesia and teredine attack.

3. Metal-organic Compounds (Table III): The incomplete data indicate that organic mercury compounds are effective against Limnoria but rather ineffective against Martesia and teredine borers. Tributyltin compounds show early initial Limnoria attack, but are resistant for long periods of time against Martesia and teredine borers.

4. Organic Compounds (Table IV): Chloro-o-phenylphenol and phenanthrene are essentially ineffective preservatives. The ether-soluble alkaloids of greenheart sawdust resisted Martesia and teredine attack during their short exposure period, but were heavily attacked by Limnoria.

5. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar Solutions (Table V): Combination treatments containing creosote, coal tar, or creosote - coal tar solutions plus an additive toxic to Limnoria are being studied. Although data are incomplete, the results to date show the following trends:

At Port Hueneme and Pearl Harbor, nearly all of the chemicals which are toxic to Limnoria and were added to coal tar, creosote, or creosote - coal tar solutions are performing well in decreasing Limnoria attack. In several instances, Limnoria attack has occurred at an early date, but the rate of progress of the attack was slower than in those panels which did not contain the additive. The rate and degree of Martesia attack is essentially unaffected by these additives. X-ray photographs show some teredine attack on these panels, expecially those containing diluted creosote or creosote - coal tar.

Panels treated with coal tar containing copper naphthenate (1 and 2%) or tributyltin oxide (1%) are much more resistant to Limnoria than those treated with coal tar only.[9] They are not, however, as resistant to Limnoria as those treated with creosote, creosote solutions, or creosote - coal tar solutions containing one of the above additives.

Aluminum oxinate (1%) does not increase Limnoria resistance when used as an additive to creosote.

6. Other Combination Treatments (Table VI): From the data obtained to date, nearly all treatments consisting of a material specifically toxic to Limnoria and a material specifically toxic to teredine borers are performing well at Port Hueneme. At Pearl Harbor, however, some of these treatments have failed because of Limnoria or Martesia attack or both. Combinations of toxic chemicals which show promise at both test sites are:

(a) p-aminophenylmercuric acetate (1%) and malachite green oxalate (2%)

(b) chlordan (5%) and malachite green oxalate (2%)

(c) copper naphthenate (3%) and tributyltin coconut fatty acid salt (1 or 5%)

(d) solubilized copper oxinate (50%) and tributyltin coconut fatty acid salt (1 or 5%)

(e) copper sulfate (14.73%) and sodium monohydrogen arsenate (20.06%)

(f) dieldrin (1 or 5%) and tributyltin coconut fatty acid salt (1 or 5%)

(g) p-dimethylaminophenylmercuric acetate (1%) and tributyltin coconut fatty acid salt (1%)

(h) toxaphene (1 or 5%) and tributyltin coconut fatty acid salt (1 or 5%)

(i) toxaphene (1 or 5%) and tributyltin oxide (1 or 5%)

(j) tributyltin coconut fatty acid salt (1, 5, or 10%) and phenylmercuric oleate (1 or 5%)

(k) tributyltin oxide (1%) and ammonium sulfide (20-24%)

(l) tributyltin oxide (10%) and copper naphthenate (3%)

Other treatments in this series have sustained teredine attack at Port Hueneme.

7. Untreated Panels and Solvent-Extracted Untreated Panels (Table VII): The tropical woods antidesma pulvinatum, greenheart, and lignum vitae are performing well after extended periods at Port Hueneme. Greenheart panels which have been extracted with acetic acid, chloroform, or methanol are about equal to greenheart according to data obtained to date. All greenheart and extracted greenheart panels have been attacked by teredine borers, and the ether-extracted panels have failed. Sea-water-extracted greenheart panels failed earlier because of Limnoria and teredine borers at Port Hueneme.[9] Afambeau, greenheart, and lignum vitae failed at Pearl Harbor chiefly because of Martesia attack. Antidesma pulvinatum has not been exposed at Pearl Harbor because of previous exposure tests of this wood in Hawaiian waters by Edmondson.[15]

DISCUSSION

According to data obtained so far, the most promising treatments for the preservation of wood in a marine environment are those which contain a combination of materials, each of which is toxic to one or more species of borer. The addition of certain organic or metal-organic compounds to creosote or creosote - coal tar solution produces a preservative which is superior to creosote or creosote - coal tar solution alone.

In the evaluation of the experimental treatment systems, the time to initial Limnoria attack has been used as one index for determining the efficacy of any given system. There are two reasons for this: (1) Limnoria attack the surface of the wood

and are thus readily detectable; (2) Limnoria, unlike teredine borers, can attack wood treated with creosote or 70-30 creosote - coal tar solution, the present standard preservatives for marine piling.

In reporting Limnoria attack, two ratings are emphasized: time to initial attack and the attack rating at the end of the total exposure period. The time to initial attack should presumably be the time required by the harbor environment to sufficiently alter the surface of the treated panel to render it susceptible to Limnoria attack. As a general rule, those treatments that delay initial attack are better than those that show initial attack after short periods of exposure.

This generalization does not hold for treatments consisting of creosote or creosote - coal tar solution containing additives that are specifically toxic to Limnoria. Frequently the presence of the additive may not alter the time to initial attack but will significantly alter the rate of progress of the attack. For example, at Pearl Harbor, panels treated with 50 percent creosote showed initial Limnoria attack in an average of 5 months, [10] and panels treated with 50 percent creosote containing 10 percent biphenyl were attacked in 5.5 months. The creosoted panels, however, were so heavily attacked by Limnoria in 18 months that they were removed from test, but the panels containing the biphenyl additive were only moderately attacked after 54 months and are still under test.

In some instances the addition to creosote or creosote - coal tar solution of a chemical specifically toxic to Limnoria does not result in an improved preservative. One or more of a number of factors that would be difficult to anticipate may operate. Among these are: (1) the quantity of additive may be too small to exert a toxic effect; (2) the additive may in some manner form a complex with some of the creosote constituents and become less toxic, more soluble, or more peptizable by sea water; and (3) the additive in the presence of creosote may be more readily detoxified by the harbor flora and fauna.

Many preservative systems listed in this report contain no creosote or creosote - coal tar solution but are composed of a combination of materials, each of which is toxic to one or more species of borer. A number of these show promise as useful preservatives. Here, too, the combination may be less effective than one might have reason to expect from the results of the exposure of the individual toxic agents. Again, interactions similar to those [illegible]iated for the interaction between creosote and a chemical additive may be in[illegible]d. It is apparent, therefore, that no definite predictions can be made about the effectiveness of a multicomponent system containing compounds each of which is known to be effective against one or more species of borers. Each system must be evaluated. Compounds which have proved effective individually and which are potentially valuable in multicomponent systems should be evaluated in such systems.

CONCLUSIONS

1. High retentions of creosote and creosote - coal tar solutions are effective against Martesia and teredine borers but not against Limnoria. Creosote and 70-30 creosote - coal tar solution have about the same preservative ability.

2. Inorganic copper and mercury compounds and copper chelates are generally effective against Limnoria only, but higher concentrations of copper naphthenate and solubilized copper oxinate have exhibited a degree of effectiveness toward all types of borers.

3. Phenylmercury compounds are effective against Limnoria; tributyltin compounds, against Martesia and teredine borers.

4. The addition of certain inorganic, organic, and metal-organic compounds and insecticides to creosote or creosote - coal tar solutions improves their resistance to Limnoria.

5. Creosote-free combination treatments containing constituents specifically toxic to each borer species show promise of being effective in marine environments.

6. Afambeau, greenheart, and lignum vitae resist Limnoria attack, but are subject to Martesia and teredine attack at Pearl Harbor and teredine attack at Port Hueneme. Antidesma pulvinatum has not been attacked by teredine borers and only slightly by Limnoria at Port Hueneme.

FUTURE PLANS

1. Exposure tests of treated wood panels now under test will be continued.

2. Treatments which show promise in panel tests will be used to impregnate full-sized piling in the NCEL treatment plant.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Messrs. Francis A. Dunwell and Joseph R. Moses of the District Public Works Office, Fourteenth Naval District, Pearl Harbor, for their assistance and cooperation in making possible the exposure of test panels at Pearl Harbor.

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14. NCEL Technical Note N-503, Cooperative Marine Piling Investigation: Phase 2 — Pile Driving at Pearl Harbor, Hawaii, by H. Hochman. 29 July 1963.

15. Bernice P. Bishop Museum. Bulletin 217, Resistance of Woods to Marine Borers in Hawaiian Waters, by C. H. Edmondson. Honolulu, Hawaii, 1955, pp. 23-4.

SYMBOLS USED IN TABLES

* This panel series, or part thereof, was still under test as of 15 August 1963.

** One or more panels in this series had been attacked by this species as of 15 August 1963.

*** One or more panels in this series were not attacked by this species during the entire peiod of harbor exposure.

N No panels in this series had been attacked by this species as of 15 August 1963.

NC Not Checked

S Panel split during cleaning operations.

BYD Panels furnished by the Bureau of Yards and Docks.

FPL Panels furnished by the Forest Products Laboratory, Madison, Wisconsin.

0 No attack.

T Trace attack.

VL Very light attack.

L Light attack.

M Moderate attack.

H Heavy attack.

VH Very heavy attack.

† Does not include the weight of ammonium sulfide solution absorbed.

NOTE: In some cases there are discrepancies between the time to initial attack and the total exposure time of the panel. This generally occurs when one or more panels in a series are not attacked by a given species. The data presented in the tables are the average of time to initial attack of those panels which were attacked by a given species, and the average of the total exposure time of all panels in the series.

X-RAY DATA: The fractions of panels attacked by teredine (No. attacked/No. exposed) and the assessments of damage, listed in Columns 7 and 8 of the tables, were determined by X-ray photographs taken in October 1963 of panels being exposed at Port Hueneme.

Table 7. Creosote and Creosote-Coal Tar Solutions

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
100% Creosote (1.8# panel)	31.0	32.5	44	M	0			34.3	7.5		15	H	0	0
100% Creosote	35.7	22	85*			1/5	T	40.8	9		17	M	0	0
	40.2	26	77	VH	0			35.7	10	18***	52.5*			
	32.7	29	76.5*			1/2	VL	42.4	5		20	H	0	C
	33.3	19.5	56	H	0			35.8	4	35***	37*			
	37.2	17.5	72.5*			2/2	T							
	29.9	16	68*											
	33.5	11	58	VH	T									
	39.1	2	48*											
	25.7	8	40.5*											
	23.3	10	38*											
	34.3	14	27.5*											
	31.1	**	24.5*											
100% Creosote (FPL)	45.8	**	48*					45.8	7.5	29***	44	VH	T	0
100% Creosote in Douglas Fir	39.8	**	61.5*					41.5	7.5	16	52.5	VH	VL	0
	41.0	2.5	48*			1/3	T	24.3	7	N	21*			
	28.1	**	24.5*											
70-30 Creosote - Coal Tar	40.4	28	85*					38.4	10		22.5	M	0	0
	27.1	14	66*					32.6	5		22	VH	0	0
	19.7	12	60*			2/4	T	30.9	4	**	37*			
	23.1	7	43	VH	0			33.2	6.5	10.5***	24	VH	T	0
	35.7	**	40.5*					37.3	5	8***	12.5	VH	T	0
	34.4	**	27.5*											
	34.8	**	24.5*											
70-30 Creosote - Coal Tar in Douglas Fir	38.5	18	61.5*					33.9	9	10.5	56*			
	41.4	4	48*											
	14.7	15	24.5*											

Table II. Inorganic Compounds

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Copper Acetate	0.38	37***	41	T	M									
1% Copper Acetate + ht. tr.	0.38	24***	37	T	M									
1% Copper Acetate in Douglas Fir	0.21	40***	49	T	M									
1% Copper Acetate + ht. tr. in Douglas Fir	0.30	32	60*											
2% Copper Acetate	0.75	34	51	T	M									
2% Copper Acetate + ht. tr.	0.74	**	60*			1/1	M							
2% Copper Acetate in Douglas Fir	0.71	**	60*											
2% Copper Acetate + ht. tr. in Douglas Fir	0.67	40	60*			1/4	L							
5% Copper Acetate	1.86	53	60*			2/4	VL							
5% Copper Acetate + ht. tr.	1.98	46	60*			2/4	VL							
5% Copper Acetate in Douglas Fir	1.14	**	60*											
5% Copper Acetate + ht. tr. in Douglas Fir	1.36	52.5	60*											
2% Copper Formate + ht. tr. in Douglas Fir	0.95	45.5	54	VL	M			0.94	12	12	14	L	VL	L
1% Copper Naphthenate	0.29 0.28	43 **	77.5* 48*			1/2	L	0.26	24.5	26.5	27.5	L	L	L
1% Copper Naphthenate in Douglas Fir	0.18	**	57.5*					0.16	26***	15	26	VL	M	VL***

Continued

Table II. Inorganic Compounds (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
3% Copper Naphthenate in Douglas Fir	0.31	**	57.5*			1/4	VL	0.45	**	**	56*			
6% Copper Naphthenate	1.18	**	77.5*					1.22	N	**	75*			
	1.31	N	48*					1.38	N	**	45*			
6% Copper Naphthenate in Douglas Fir	0.46	**	57.5*					0.32	20***	20	56*			
1% Copper Sulfate in Redwood	0.35	**	76.5*			2/2	T	0.38		9	11	0	H	0
	0.37	**	40.5*											
1% Copper Sulfate in Western Red Cedar	0.34	29	76.5*			1/1	T	0.46		6	9.5	0	H	0
2% Copper Sulfate in Douglas Fir	0.55	**	54*			2/3	M							
2% Copper Sulfate + ht. tr. in Douglas Fir	0.71	29.5	42	VL	M									
5% Copper Sulfate in Douglas Fir	1.54	**	59*			2/4	L							
5% Copper Sulfate + ht. tr. in Douglas Fir	1.75	34	59*											
10% Copper Sulfate + ht. tr.	3.95	23***	31.5	T	M									
10% Copper Sulfate in Douglas Fir	3.19	**	59*			4/4	L							
10% Copper Sulfate + ht. tr. in Douglas Fir	3.51	**	59*											

Continued

Table II. Inorganic Compounds (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test	
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
10% Copper Sulfate in Redwood	3.55	**	76.5*			1/2	T	3.32		17	17	0	L	0
10% Copper Sulfate in Western Red Cedar	2.52	N	76.5*			1/1	T	3.88		9	11.5	0	M	VL
10% Solubilized Copper Oxinate	3.22	38	76.5*			2/2	VL	3.18		14.5	18	0	H	T
25% Solubilized Copper Oxinate	7.3	**	76.5*			1/2	T	8.1	22***	21	30.5	VL	M	VL
50% Solubilized Copper Oxinate	15.5	**	76.5*					14.9	**	37.5	75*			
5% Cuprammine Sulfate	1.33	**	61.5*					1.38	20	21***	23	H	VL	M
5% Cuprammine Sulfate + ht. tr.	1.85	39	60*					1.89	15	21***	25.5	H	VL	M
5% Cuprammine Sulfate in Douglas Fir	2.45	29	61.5*					2.33	N	31	56*			
5% Cuprammine Sulfate + ht. tr. in Douglas Fir	1.59	**	59*					1.47		22.5	29	0	M	T***
5% Cupric Ethylenediamine Sulfate + ht. tr.	2.01	30***	30	T	M			1.91	9	11	12	VL	VL	H
5% Cupric Ethylenediamine Sulfate in Douglas Fir	1.23	47***	59*			1/3	L	1.44	17***	16	24	VL	VL	VL***
5% Cupric Ethylenediamine Sulfate + ht. tr. in Douglas Fir	1.69	**	57.5*			3/3	L	1.85	17***	12	20	VL	M	T***
5% Mercuric Acetate	2.03	35	66*					2.06	26	19	31	T	H	T***
5% Mercuric Acetate + ht. tr.	2.10	34	66*					2.26		13.5	13.5	0	L	H

Table III. Metal-organic Compounds 1/

Treatment	Port Hueneme					Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.		Lim.	Mart.		Lim.	Mart.	Ter.
1% p-Aminophenylmercuric Acetate	0.39 0.41	19*** 15	30.5 38	T VL	H H	0.37	11***	8.5	13	T	L	H
1% p-Dimethylaminophenylmercuric Acetate in Douglas Fir	0.35	**	53	0	H	0.35	30***	14	27	T	H	VL***
1% Tributyltin Coconut Fatty Acid Salt	0.27	N	68*			0.27	4	N	45*			
10% Tributyltin Coconut Fatty Acid Salt	2.91	**	24.5*			2.93	9	N	21*			
0.5% Tributyltin Oxide	0.13	**	61.5*									
1% Tributyltin Oxide	0.27	N	61.5*			0.25 0.26	10 5	 N	47 49.5*	VH	0	0
10% Tributyltin Oxide	2.66	N	24.5*			2.66	**	N	21*			
1% Triphenyltin Acetate	0.30	**	24.5*			0.31	5	N	21*			

1/ X-ray photographs taken at Port Hueneme in October 1963 showed no teredine attack on treatments under test.

Table IV. Organic Compounds

Treatment	Port Hueneme					Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test	
				Lim.	Ter.		Lim.	Mart.		Lim.	Mart.	Ter.
5% Chloro-o-phenylphenol	1.61	3	14	L	H	1.53	3	4.5	5.5	H	L	H
1% Ether Soluble Alkaloids of Greenheart Sawdust						0.36	2		5	VH	0	T***
2% Ether Soluble Alkaloids of Greenheart Sawdust	0.71	2.5	12	VH	T***	0.67	2		6	VH	0	T***
10% Phenanthrene	3.2	4	14	H	L	2.9	3	4	5	L	M	T

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Aluminum Oxinate in Creosote (1/8" panel)	0.35 34.5	37	94.5*					0.34 33.7	6	9	20	M	T	0
0.9% p-Aminophenylmercuric Acetate + 100% Creosote (double treatment)	0.28 28.5	**	38*					0.26 23.7	12	18	37*			
10% Biphenyl 50% Creosote	3.0 15.6	11	54*					3.1 15.7	5.5	12.5	54*			
								3.1 15.5	**	**	49.5*			
5% Chlordan 50% Creosote	1.51 15.1	6	48*					1.53 15.3	21***	13	35	T	H	0
5% Chlordan 50% 70-30 Creosote - Coal Tar	1.52 15.2	3	48*			1/4	L	1.59 15.9	19***	15	32	T	H	0
10% Chlordan 50% Creosote	2.45 12.2	10.5	48*					3.02 14.5	**	21	45*			
10% Chlordan 50% 70-30 Creosote - Coal Tar	3.49 17.5	6	48*					3.07 15.5		14	31	0	H	0
0.5% Copper Naphthenate 50% Coal Tar	0.15 15.2	22.5	65	L	H			0.14 13.6	9	9	20	M	M	VL
1% Copper Naphthenate 50% Coal Tar	0.28 14.1	**	66*					0.26 12.9	18	NC	39	VH	M	L
2% Copper Naphthenate 50% Coal Tar	0.60 15.0	16	37	H	0			0.59 14.9	10	5.5	17	M	M	0

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
3% Copper Naphthenate 50% Creosote in Douglas Fir	0.41 8.6	**	57.5*					0.64 10.7	**	**	56*			
3% Copper Naphthenate 50% 70-30 Creosote - Coal Tar in Douglas Fir	0.56 9.3	N	57.5*					0.43 7.1	22.5	21	56*			
1% Copper Oxinate in Creosote (1/8" panel)	0.34 33.1	39	85S	L	0			0.35 35.0	10	8	34	H	T	0
2.5% Copper Oxinate in Creosote (1/8" panel)	0.58 22.2	35	94.5*					0.72 27.3	6	7	17	L	L	0
5% Copper Oxinate in Creosote (1/8" panel)	1.58 30.0	36	64	H	0			1.45 27.5	6	6	15	M	L	0
	1.30 24.4	32	63S	M	0									
3% Solubilized Copper Oxinate 50% Creosote	0.50 8.2	N	54*					0.59 9.9	22		panel lost			
								0.46 7.7	27	18	41	L	M	0
0.4% Copper Stearate in Creosote	0.13 34.1	**	24.5*					0.13 31.7	9	N	21*			
6% Copper Sulfate 100% Creosote (double treatment)	2.0 36.9	N	27.5*					2.0 34.6	**	21	37*			

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage				Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				When Removed From Test		X-ray Oct 1963 Teredine								
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
12% Copper Sulfate 100% Creosote (double treatment)	5.2 35.8	N	27.5*					5.1 34.5	26	22	37*			
14.73% Copper Sulfate 20.06% Sodium mono H Arsenate 100% Creosote (triple treatment) (FPL)	3.23 3.01 38.7	N	48*					3.23 3.01 38.7	N	**	45*			
5.3% Copper Salt of Naphthenic Acid 50% Creosote	1.64 15.5	7	61.5*					1.53 15.1	9	10.5	26	H	VL	0
1% Dieldrin 50% Creosote	0.29 14.8	**	57.5*			2/4	L	0.29 14.2		8	32	0	H	0
1% Dieldrin 50% Creosote in Douglas Fir	0.22 10.9	**	57.5*			1/2	L	0.24 11.8	**	9	56*			
1% Dieldrin in Creosote	0.35 33.2	**	57.5*					0.34 33.2	30.5	23	56*			
1% Dieldrin in Creosote in Douglas Fir	0.22 21.6	**	57.5*			3/4	VL	0.22 22.0	**	10	56*			
1% Dieldrin 50% 70-30 Creosote - Coal Tar	0.30 15.1	19	57.5*			3/4	L	0.31 15.5		8	36	0	M	T***
1% Dieldrin 50% 70-30 Creosote - Coal Tar in Douglas Fir	0.25 12.8	**	57.5*			1/4	T	0.20 9.9		8	34	0	M	T***
1% Dieldrin in 70-30 Creosote - Coal Tar	0.29 28.9	**	57.5*					0.32 31.5	**	20	56*			

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test	
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Dieldrin in 70-30 Creosote - Coal Tar in Douglas Fir	0.23 22.7	**	57.5*					0.25 24.7	**	24	56*			
5% Dieldrin 50% Creosote	1.53 15.3	**	54*					1.31 13.1		8	34	0	H	0
								0.84 8.4		6	28	0	M	0
5% Dieldrin 50% 70-30 Creosote - Coal Tar	1.50 15.0	14	54*			3/4	VL	1.48 14.8		9	32	0	H	0
1% p-Dimethylaminophenylmercuric Acetate 100% Creosote (double treatment)	0.38 29.3	25	38*					0.39 33.5	13	28	37*			
10% Diphenylmethane 50% Creosote	2.81 14.1	9	54*			1/3	VL	3.07 15.4	6	11.5	41	H	H	0
1% Endrin 50% Creosote in Douglas Fir	0.24 11.8	**	57.5*			2/3	L	0.27 13.4	N	11	56*			
1% Endrin in Creosote in Douglas Fir	0.24 24.1	**	57.5*					0.26 26.0	**	9	56*			
1% Endrin 50% 70-30 Creosote - Coal Tar in Douglas Fir	0.25 12.2	**	57.5*			1/4	H	0.25 12.4	N	11	56*			
1% Endrin in 70-30 Creosote - Coal Tar in Douglas Fir	0.24 23.7	**	57.5*					0.23 23.2	N	11.5	56*			

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test	
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
5% Endrin 50% Creosote	1.41 14.1	**	54*			1/4	T	1.43 14.3		1	25	0	H	0
								1.38 13.8		6	45	0	VH	0
5% Endrin 50% 70-30 Creosote - Coal Tar	1.67 16.7	14	54*			2/4	T	1.49 14.9	N	7	54*			
2% Malachite Green Oxalate 10% Creosote (double treatment)	0.79 2.87	7	40.5*					0.79 2.89	5.5	6	11	VH	L	0
2% Malachite Green Oxalate 25% Creosote (double treatment)	0.77 7.28	6	40.5*			1/4	T	0.76 7.12	5	6	12	VH	M	0
2% Malachite Green Oxalate 50% Creosote (double treatment)	0.78 15.5	5	40.5*					0.81 16.7	5.5	7	16	VH	M	0
2% Malachite Green Oxalate 100% Creosote (double treatment)	0.76 33.8	**	40.5*					0.77 34.0	7	10	27*			
5% Manganous Oxinate in Creosote (1/8" panel)	1.60 30.3	35	62.5*	L	0			1.87 34.8	11	11.5	185	VL	VL	0
	1.86 37.0	36	88.5*											
14.86% Nickel Sulfate 20.06% Sodium mono H Arsenate 100% Creosote (triple treatment) (FPL)	3.71 3.43 20.7	**	48*					3.71 3.43 20.7		15	31	0	H	0
10% Phenyl Ether 50% Creosote	3.02 15.1	7	54*					2.91 14.6	7	10	50	M	M	0

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		Damage X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Phenylmercuric Chloride in Creosote	0.26 26.2	28.5	85*			1/1	T	0.42 41.9	12.5	15.5	43	M	L	0
1% Phenylmercuric Chloride 50% 70-30 Creosote - Coal Tar in Douglas Fir	0.23 11.8	37	57.5*					0.23 11.4	**	7	49.5*			
1% Phenylmercuric Chloride in 70-30 Creosote - Coal Tar in Douglas Fir	0.16 15.1	16	57.5*			1/4	T	0.19 20.9	22	17	56*			
1% Phenylmercuric Oleate in Creosote	0.37 36.8	29.5	85*			1/2	VL	0.37 37.3	5	NC	11	M	T	0
1% Phenylmercuric Oleate (solid) in Creosote	0.37 36.9	**	27.5*					0.27 26.8	7	**	27*			
1% Phenylmercuric Oleate (solid) in 70-30 Creosote - Coal Tar Solution	0.17 16.1	17.5*	28*					0.14 14.2	7.5	6	14	VH	L	0
1% Phenylmercuric Oleate 10% Creosote 30% Coal Tar	0.36 3.6 10.7	29.5	56.5	VH	0			0.32 3.2 9.5	6	15	15	M	M	0
1% Phenylmercuric Oleate 50% Creosote 10% Coal Tar	0.27 13.7 2.7	30	82.5*			1/1	T	0.26 12.9 2.6	9	NC	20	M	T	0
1% Phenylmercuric Oleate 50% Creosote 30% Coal Tar	0.31 15.7 9.4	34	82.5*					0.37 18.6 11.1	o	9***	25	VH	VL	0

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Phenylmercuric Oleate 66% Creosote 30% Coal Tar	0.34 22.5 10.3	**	82.5*					0.33 21.5 9.8	17	23	49	VH	H	0
1% Phenylmercuric Oleate 74% Creosote 10% Coal Tar	0.20 15.1 2.0	34	82.5*					0.29 21.1 2.9	7.5	18	56	H	L	0
5% Phenylmercuric Oleate 10% Coal Tar	1.20 2.38	30***	62	T	M			1.15 2.29	15	19.5	20.5	VL	H	VL
5% Phenylmercuric Oleate 30% Coal Tar	1.11 6.63	33	69	VL	H			1.16 7.26	17***	16.5	29	T	H	L
5% Phenylmercuric Oleate 50% Creosote	1.97 19.7	29	85*					1.74 17.4	17.5	15.5	36	H	M	T
5% Phenylmercuric Oleate (solid) in Creosote	1.76 33.2	N	27.5*					1.56 29.5	12	**	27*			
	1.76 33.3	N	24.5*					1.49 28.1	11	**	21*			
5% Phenylmercuric Oleate (solid) in Creosote in Douglas Fir	0.89 16.9	**	24.5*					0.70 13.3	7	**	21*			
5% Phenylmercuric Oleate (solid) in 70-30 Creosote - Coal Tar Solution	1.00 19.0	N	27.5*			1/4	T	0.79 14.9	7	**	27*			
5% Phenylmercuric Oleate 10% Creosote 10% Coal Tar	1.14 2.26 2.26	40	82.5*			1/2	L	1.27 2.52 2.52	18	21	36	T	M	VL

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage				Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				When Removed From Test		X-ray Oct 1963 Teredine								
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
5% Phenylmercuric Oleate 10% Creosote 30% Coal Tar	1.57 3.13 9.39	34.5	82.5*			1/1	T	1.84 3.67 10.55		20	28	0	H	0
5% Phenylmercuric Oleate 50% Creosote 10% Coal Tar	1.93 19.3 3.86	41	82.5*					1.65 16.5 3.27	19	22.5	39.5	M	L	0
5% Phenylmercuric Oleate 50% Creosote 30% Coal Tar	1.53 15.3 9.23	38.5	82.5*					1.69 16.9 10.1	27	22.5	51	VH	M	0
5% Phenylmercuric Oleate 51.2% Creosote 30% Coal Tar	1.79 18.4 10.2	36	82.5*					1.60 16.4 9.58	19	21.5	46.5	H	VL	0
5% Phenylmercuric Oleate 71% Creosote 10% Coal Tar	1.75 24.8 3.50	38	82.5*					2.03 28.8 4.05	25.5	15.5	58	VH	L	0
6% Phenylmercuric Oleate in Creosote	2.19 39.6	31	85*					2.48 41.4	**	24	53	L	M	0
1% Solubilized Tributyltin Oxide 50% Coal Tar	0.33 16.3	11	43	H	T***			0.31 15.4	6.5	12***	21	VH	L	0
1% Toxaphene 50% Creosote	0.29 14.5	4	38*			1/4	M	0.30 14.8	2.5	25	37*			
1% Toxaphene 50% Creosote in Douglas Fir	0.25 12.4	**	38*					0.26 12.6	2	13	panels lost			

Continued

Table V. Combination Treatments Containing Creosote, Coal Tar, or Creosote - Coal Tar (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage				Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				When Removed From Test		X-ray Oct 1963 Teredine								
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% Toxaphene in Creosote	0.30 29.3	9.5	38*					0.34 33.6	7	**	37*			
1% Toxaphene in Creosote in Douglas Fir	0.24 23.6	9	38*			1/3	T	0.25 23.8	2	**	37*			
5% Toxaphene 50% Creosote	1.62 16.2	**	38*			2/4	VL	1.50 15.0	5	18.5	37*			
5% Toxaphene 50% Creosote in Douglas Fir	1.42 14.2	**	38*					1.40 14.0	**	19	37*			
5% Toxaphene in Creosote	1.50 28.4	**	38*					1.64 30.9	4	23	37*			
5% Toxaphene in Creosote in Douglas Fir	1.19 22.5	4	38*			1/4	L	1.07 20.1	4.5	15.5	37*			
0.5% Tributyltin Oxide 50% Coal Tar	0.15 14.6	12	40	VH	0									
1% Tributyltin Oxide 50% Coal Tar	0.27 13.5	12.5	61.5*					0.31 15.8	6		31	VH	0	0
1% Tributyltin Oxide 50% Creosote	0.33 16.6	**	54*					0.30 14.6	11.5	42***	54*			
1% Tributyltin Oxide 2% Toxaphene in Creosote (BYD)								1/	6	N	15*			
2% Tributyltin Oxide in Creosote (BYD)								1/	10	N	15*			

1/ Data not furnished.

Table VI. Other Combination Treatments

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb./cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct. 1963 Teredine		Weight Solute Absorbed (lb./cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
1% p-Aminophenylmercuric Acetate + 2% Malachite Green Oxalate (double treatment)	0.39 0.76	**	38*					0.39 0.77	29	21	37*			
1% p-Aminophenylmercuric Acetate + 1% Tributyltin Coconut Fatty Acid Salt (double treatment)	0.39 0.27	N	38*			1/2	T	0.39 0.27	12.5	22	29	H	L	T**
5% Biphenyl 2% Malachite Green Oxalate	1.66 0.66	4	41	VH	0			1.75 0.70	3	7.5	13	VH	L	0
5% Chlordan 2% Malachite Green Oxalate	1.87 0.72	**	48*					1.73 0.69	**	16	45*			
2% Copper Acetate 1% Malachite Green Oxalate	0.75 0.38	41	60*					0.75 0.38	10.5	11.5	15	H	L	0
2% Copper Acetate 1% Malachite Green Oxalate in Douglas Fir	1.00 0.51	**	57.5*					1.14 0.57	18	12	18	L	M	0
2% Copper Epoxy 1% Malachite Green Oxalate	0.67 0.34	12	21	M	H			0.66 0.33		5	9	0	M	T
3% Copper Naphthenate 50% Linseed Oil	0.61 10.1	N	60*					0.66 11.0	34	28	49	M	L	T
3% Copper Naphthenate 50% Linseed Oil in Douglas Fir	0.35 5.9	N	60*					0.21 3.5	23	22	33	M	M	0
3% Copper Naphthenate 1% Tributyltin Coconut Fatty Acid Salt	0.69 0.23	N	38*					0.75 0.25	N	N	37*			

Table VI. Other Combination Treatments (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
3% Copper Naphthenate 5% Tributyltin Coconut Fatty Acid Salt	0.82 1.35	**	38*					0.84 1.40	N	N	37*			
5% Copper Sulfate 3.2% PVM/MA	1.43 0.92	41.5	54	L	L									
10% Copper Sulfate 3.2% PVM/MA	3.72 1.22	42	61.5*			1/2	T							
50% Solubilized Copper Oxinate 1% Tributyltin Coconut Fatty Acid Salt	12.5 0.25	N	40.5*					10.6 0.22	N	**	37*			
50% Solubilized Copper Oxinate 5% Tributyltin Coconut Fatty Acid Salt	13.0 1.30	**	40.5*					13.2 1.32	N	N	37*			
14.73% Copper Sulfate 20.06% Sodium mono H Arsenate (double treatment) (FPL)	3.23 3.01	N	48*					3.23 3.01		35	40	0	L	0
5% Cuprammine Sulfate 3.2% PVM/MA	1.83 1.17	**	61.5*											
1% Dieldrin 1% Malachite Green Oxalate	0.30 0.30	**	54*			2/3	L	0.32 0.32		4.5	9	0	H	0
								0.33 0.33		4	12.5	0	H	T***
1% Dieldrin 1% Tributyltin Coconut Fatty Acid Salt	0.30 0.30	**	40.5*					0.25 0.25	6.5	N	37*			

Continued

Table VI. Other Combination Treatments (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test	
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
5% Dieldrin	1.44							1.32						
5% Tributyltin Coconut Fatty Acid Salt	1.44	**	40.5*					1.32	**	N	37*			
1% p-Dimethylaminophenylmercuric Acetate	0.39							0.40						
1% Tributyltin Coconut Fatty Acid Salt (double treatment)	0.27	**	38*					0.28	15	**	37*			
1% p-Dimethylaminophenylmercuric Acetate	0.38							0.40						
2% Malachite Green Oxalate (double treatment)	0.75	**	38*					0.79	19	15	30	H	H	0
5% Diphenylmethane	1.60							1.66						
2% Malachite Green Oxalate	0.64	3	48.5	M	0			0.67	4	7	12	VH	L	0
1% Endrin	0.36							0.32						
1% Malachite Green Oxalate	0.36	**	54*					0.32		4.5	10.5	0	M	0
2% Malachite Green Oxalate	0.74							0.78						
5% Dieldrin (double treatment)	1.43	N	54*					1.52		7	19	0	H	0
2% Malachite Green Oxalate	0.73							0.75						
5% Endrin (double treatment)	1.44	N	54*					1.44		10	36	0	H	0
2% Malachite Green Oxalate	0.34							0.86						
1% Toxaphene (double treatment)	0.31	**	27.5*					0.29		6	16	0	H	0
2% Malachite Green Oxalate	0.79							0.57						
5% Toxaphene (double treatment)	1.45	**	27.5*					1.24	N	9	27*			

Continued

Table VI. Other Combination Treatments (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
14.36% Nickel Sulfate 20.06% Sodium mono H Arsenate (double treatment) (FPL)	3.71 3.43	28***	31	T	M			3.71 3.43	11.5***	11	15	T	H	VL
14% Phenylmercuric Oleate 50% Linseed Oil	3.99 14.3	**	60*					3.87 13.7	20	18	34.5	H	M	0
14% Phenylmercuric Oleate 50% Linseed Oil in Douglas Fir	1.80 6.5	**	60*			1/2	VL	2.38 8.5	17	12	29	L	L	L
1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt	0.26 0.26	**	38*					0.28 0.28	7	N	37*			
1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt in Douglas Fir	0.18 0.18	6	38*					0.26 0.26	5	N	37*			
1% Toxaphene 1% Tributyltin Oxide	0.27 0.27	N	38*					0.25 0.25	9.5	N	37*			
1% Toxaphene 1% Tributyltin Oxide in Douglas Fir	0.27 0.27	**	38*					0.22 0.22	*	N	37*			
1% Toxaphene 5% Tributyltin Oxide	0.31 1.54	N	24.5*					0.28 1.44	13.5	N	21*			
1% Toxaphene 10% Tributyltin Oxide	0.29 2.81	**	24.5*					0.33 3.27	N	N	21*			
5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt	1.40 1.40	N	38*					1.41 1.41	**	N	37*			

Continued

Table VI. Other Combination Treatments (Cont'd)

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt in Douglas Fir	1.29 1.29	13	38*					1.29 1.29	7	N	37*			
5% Toxaphene 1% Tributyltin Oxide	1.51 0.30	**	24.5*					1.39 0.28	7	N	21*			
5% Toxaphene 5% Tributyltin Oxide	1.34 1.34	N	38*					1.39 1.39	**	N	37*			
	1.59 1.59	N	24.5*					1.47 1.47	**	N	21*			
5% Toxaphene 5% Tributyltin Oxide in Douglas Fir	1.35 1.35	**	38*					1.36 1.36	18	N	37*			
5% Toxaphene 10% Tributyltin Oxide	1.67 3.29	**	24.5*					1.57 3.13	**	N	21*			
1% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	0.29 0.29	**	24.5*					0.31 0.31	5		11	H	0	L***
1% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	0.26 1.32	**	24.5*					0.28 1.41	8	17	21*			
5% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	1.43 0.28	**	24.5*					1.34 0.27	8	N	21*			
5% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	1.52 1.52	N	24.5*					1.52 1.52	9.5	17	21*			

Continued

Table VI. Other Combination Treatments (Cont'd)

Treatment	Port Hueneme							Pearl Harbor					
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage				Weight Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				When Removed From Test		X-ray Oct 1963 Teredine								
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
10% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate	3.20 0.32	**	24.5*					2.97 0.30	6	N	21*			
10% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate	2.95 1.48	**	24.5*					3.03 1.52			panels lost			
1% Tributyltin Oxide 20-24% Ammonium Sulfide (double treatment)	0.28†	**	48*					0.27†	5	**	45*			
1% Tributyltin Oxide 3% Copper Naphthenate	0.27 0.82	N	24.5*					0.27 0.81	N	N	21*			
5% Tributyltin Oxide 3% Copper Naphthenate	1.59 0.96	N	24.5*					1.32 0.79	N	N	21*			
10% Tributyltin Oxide 3% Copper Naphthenate	2.89 0.84	N	24.5*					3.11 0.94	**	N	21*			
1% Tributyltin Oxide 1% α, β-1, 2, 3, 4, 7, 7-Hexachloiobicyclo-[2.2.1]-2-heptene-5, 6-bisoxymethylene Sulfite in #5 Fuel Oil (BYD)								1/	7		15*			
1% Tributyltin Oxide 2% Toxaphene in #5 Fuel Oil (BYD)								1/	3.5		15*			

1/ Data not furnished.

Table VII. Untreated Panels and Solvent-Extracted Untreated Panels

Treatment	Port Hueneme							Pearl Harbor						
	Weight Solute Absorbed (lb/cu ft)	Months to Initial Limnoria Attack	Total Exposure Time (mo)	Damage When Removed From Test		X-ray Oct 1963 Teredine		Months Solute Absorbed (lb/cu ft)	Months to Initial Attack		Total Exposure Time (mo)	Damage When Removed From Test		
				Lim.	Ter.	Fraction	Rating		Lim.	Mart.		Lim.	Mart.	Ter.
Afambeau		**	57.5*							8	22	0	H	0
Antidesma Pulvinatum		**	48*											
Greenheart		N	75*											
		N	57.5*			1/1	M			5	13	0	H	0
		**	54*			3/3	H							
Greenheart, acetic acid extracted		N	75*			1/1	L							
Greenheart, chloroform extracted		**	75*			1/1	M							
Greenheart, ether extracted			56	0	H									
Greenheart, methanol extracted		N	75*			1/1	M							
Lignum Vitae		**	75*			2/2	L			11	12	0	M	M

Appendix

SUMMARY OF PANELS NOT ATTACKED BY ONE OR MORE SPECIES OF MARINE BORERS

Treated panels and naturally resistant wood panels which have not been attacked by one or more species of marine borers either during their entire period of exposure or as of 15 August 1963 are plotted in Figures 1 through 5. The numbers plotted on the figures refer to the treatments listed in Table VIII.

For those panels which sustained no attack by one or two species of marine borers during their entire harbor exposure, reference to the proper table (I through VII) will show that removal was necessary because of attack by other species of borers.

Teredine attack can only be definitely determined by X-ray photography or by removing a panel from test and sawing it in two.

Table VIII. Panels and Treatments Plotted in Figures 1-5

No.	Treatment
1	100% Creosote (1/8" panel)
2	100% Creosote
3	100% Creosote
4	100% Creosote (FPL)
5	70-30 Creosote - Coal Tar
6	70-30 Creosote - Coal Tar
7	6% Copper Naphthenate
7A	6% Copper Naphthenate
8	10% Copper Sulfate in Western Red Cedar
9	1% Tributyltin Coconut Fatty Acid Salt
10	10% Tributyltin Coconut Fatty Acid Salt
11	1% Tributyltin Oxide
12	10% Tributyltin Oxide
13	1% Triphenyltin Acetate
14	5% Chlordan 50% Creosote
15	5% Chlordan 50% 70-30 Creosote - Coal Tar
16	10% Chlordan 50% 70-30 Creosote - Coal Tar
17	3% Copper Naphthenate 50% 70-30 Creosote - Coal Tar in Douglas Fir
32	5% Manganous Oxinate in Creosote (1/8" panel)
33	10% Phenyl Ether 50% Creosote
34	1% Phenylmercuric Chloride in Creosote
35	1% Phenylmercuric Oleate (solid) in 70-30 Creosote - Coal Tar
36	1% Phenylmercuric Oleate 66% Creosote 30% Coal Tar
37	1% Phenylmercuric Oleate 74% Creosote 10% Coal Tar
38	5% Phenylmercuric Oleate (solid) in Creosote
39	5% Phenylmercuric Oleate (solid) in Creosote
40	5% Phenylmercuric Oleate (solid) in 70-30 Creosote - Coal Tar Solution
41	6% Phenylmercuric Oleate in Creosote
42	0.5% Tributyltin Oxide 50% Coal Tar
43	1% Tributyltin Oxide 2% Toxaphene in Creosote (BYD)
57	5% Diphenylmethane 2% Malachite Green Oxalate
58	2% Malachite Green Oxalate 5% Dieldrin (double treatment)
59	2% Malachite Green Oxalate 5% Endrin (double treatment)
60	2% Malachite Green Oxalate 1% Toxaphene (double treatment)
61	2% Malachite Green Oxalate 5% Toxaphene (double treatment)
62	1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt
63	1% Toxaphene 1% Tributyltin Coconut Fatty Acid Salt in Douglas Fir
64	1% Toxaphene 1% Tributyltin Oxide
65	1% Toxaphene 5% Tributyltin Oxide
66	1% Toxaphene 10% Tributyltin Oxide
67	5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt
68	5% Toxaphene 5% Tributyltin Coconut Fatty Acid Salt in Douglas Fir
69	5% Toxaphene 1% Tributyltin Oxide

No.	Treatment
18	1% Copper Oxinate in Creosote (1/8" panel)
19	5% Copper Oxinate in Creosote (1/8" panel)
20	3% Solubilized Copper Oxinate 50% Creosote
21	0.4% Copper Stearate in Creosote
22	6% Copper Sulfate 100% Creosote (double treatment)
23	12% Copper Sulfate 100% Creosote (double treatment)
24	14.73% Copper Sulfate 20.06% Sodium mono H Arsenate 100% Creosote (triple treatment) (FPL)
25	1% Dieldrin 50% 70-30 Creosote - Coal Tar
26	5% Dieldrin 50% 70-30 Creosote - Coal Tar
27	10% Diphenylmethane 50% Creosote
28	1% Endrin 50% 70-30 Creosote - Coal Tar in Douglas Fir
29	5% Endrin 50% Creosote
30	5% Endrin 50% 70-30 Creosote - Coal Tar
31	2% Malachite Green Oxalate 50% Creosote (double treatment)
44	2% Tributyltin Oxide in Creosote (BYD)
45	1% p-Aminophenylmercuric Acetate 1% Tributyltin Coconut Fatty Acid Salt (double treatment)
46	5% Biphenyl 2% Malachite Green Oxalate
47	3% Copper Naphthenate 50% Linseed Oil
48	3% Copper Naphthenate 50% Linseed Oil in Douglas Fir
49	3% Copper Naphthenate 1% Tributyltin Coconut Fatty Acid Salt
50	3% Copper Naphthenate 5% Tributyltin Coconut Fatty Acid Salt
51	50% Solubilized Copper Oxinate 1% Tributyltin Coconut Fatty Acid Salt
52	50% Solubilized Copper Oxinate 5% Tributyltin Coconut Fatty Acid Salt
53	14.73% Copper Sulfate 20.06% Sodium mono H Arsenate (double treatment) (FPL)
54	1% Dieldrin 1% Tributyltin Coconut Fatty Acid Salt
55	5% Dieldrin 5% Tributyltin Coconut Fatty Acid Salt
56	1% p-Dimethylaminophenylmercuric Acetate 2% Malachite Green Oxalate (double treatment)
70	5% Toxaphene 5% Tributyltin Oxide
71	5% Toxaphene 5% Tributyltin Oxide
72	5% Toxaphene 5% Tributyltin Oxide in Douglas Fir
73	5% Toxaphene 10% Tributyltin Oxide
74	1% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate
75	5% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate
76	5% Tributyltin Coconut Fatty Acid Salt 5% Phenylmercuric Oleate
77	10% Tributyltin Coconut Fatty Acid Salt 1% Phenylmercuric Oleate
78	1% Tributyltin Oxide 3% Copper Naphthenate
79	5% Tributyltin Oxide 3% Copper Naphthenate
80	10% Tributyltin Oxide 3% Copper Naphthenate
81	Greenheart
82	Greenheart
83	Greenheart, acetic acid extracted
84	Greenheart, methanol extracted

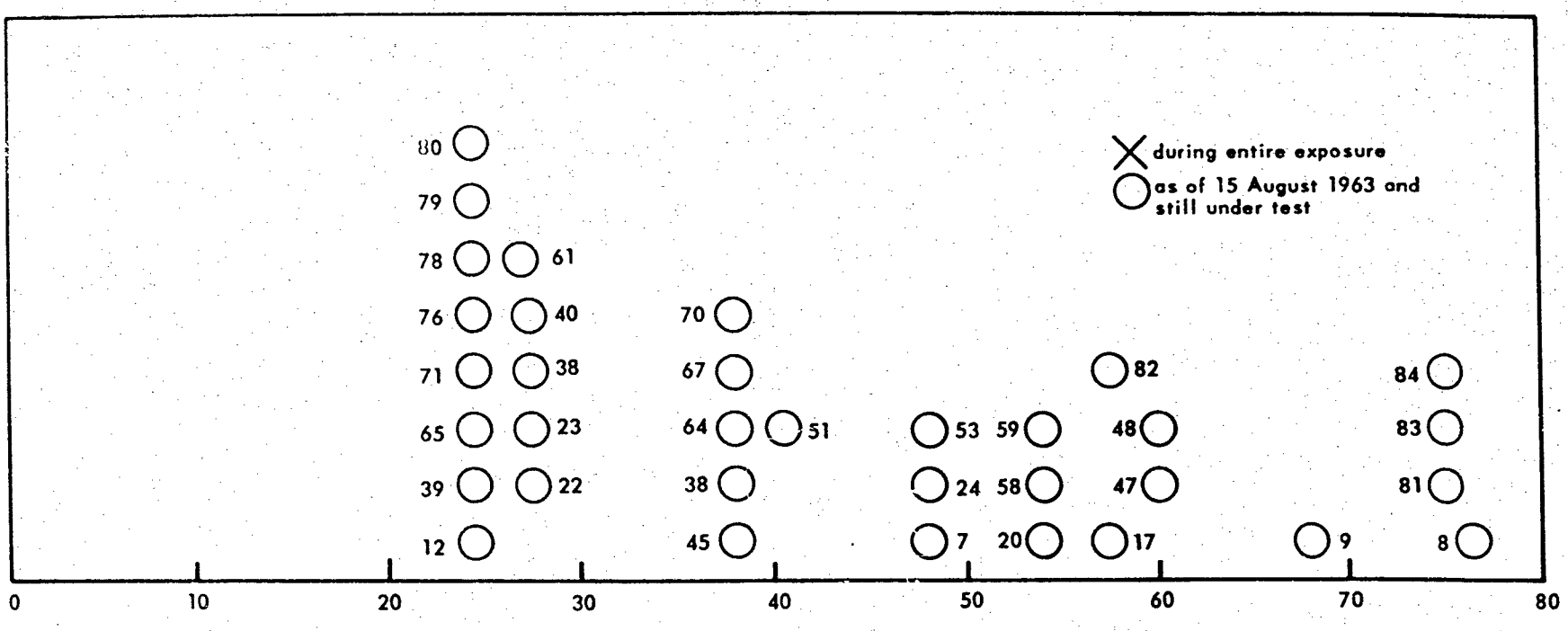

Figure 1. Port Hueneme panels not attacked by Limnoria during entire exposure or as of 15 August 1963.

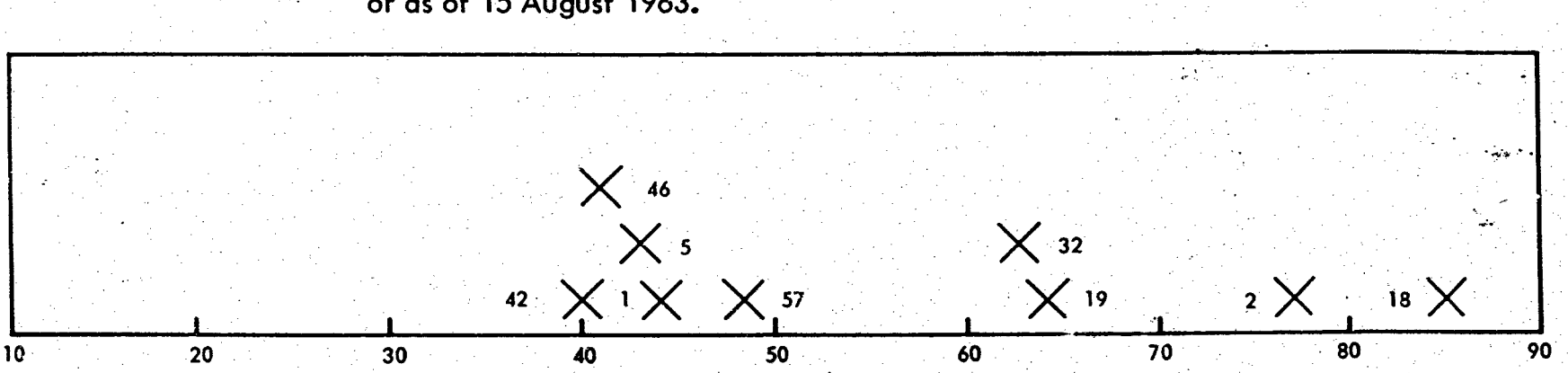

Figure 2. Port Hueneme panels not attacked by teredine borers during entire exposure.

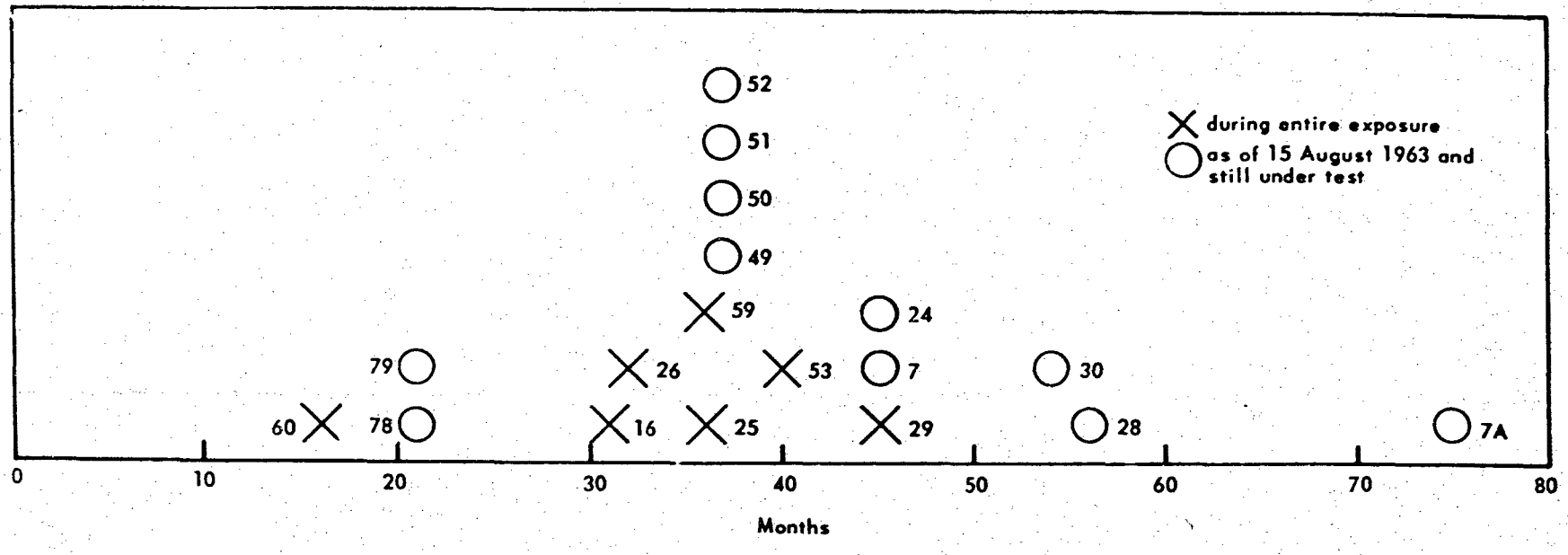

Figure 3. Pearl Harbor panels not attacked by Limnoria during entire exposure or as of 15 August 1963.

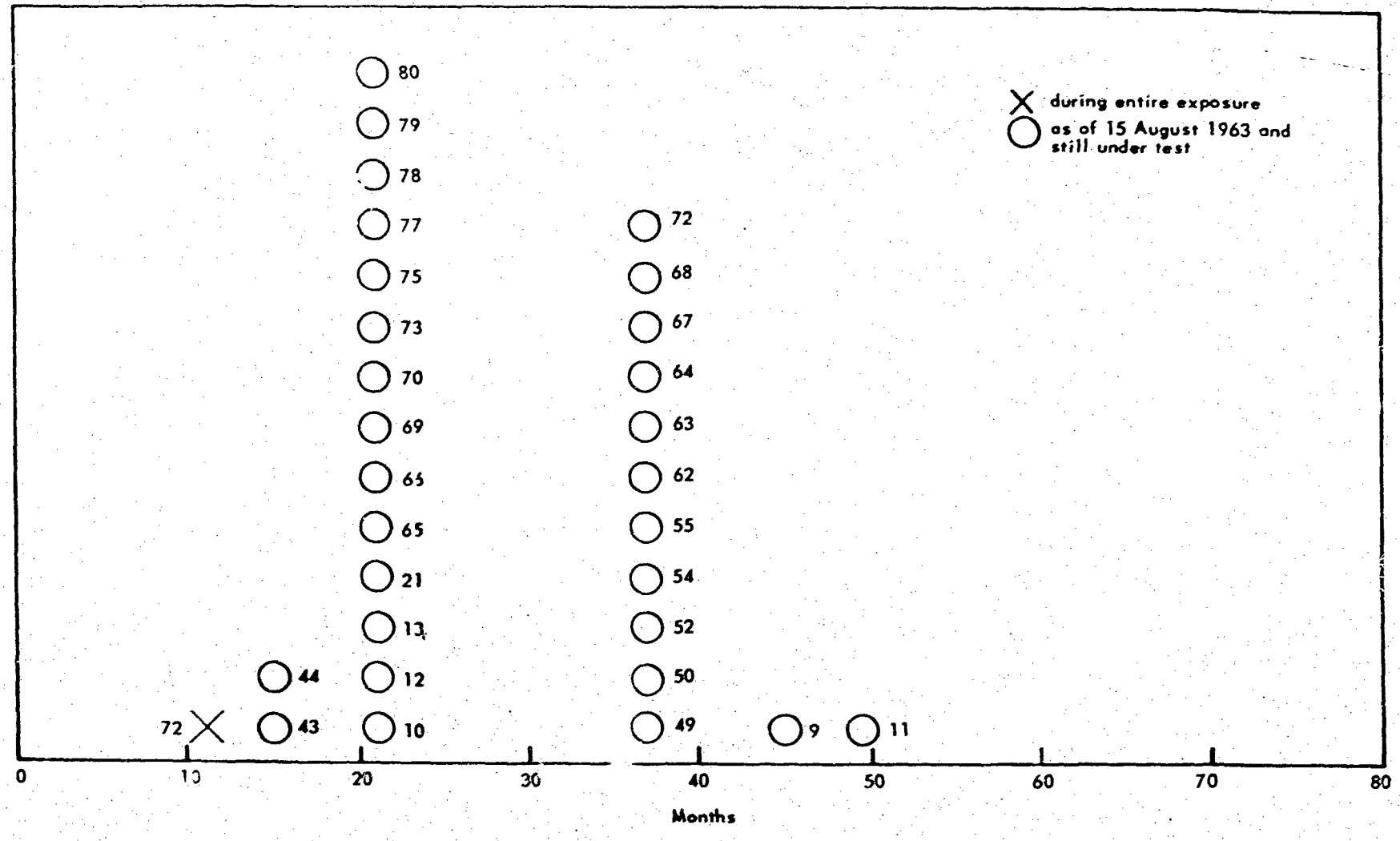

Figure 4. Pearl Harbor panels not attacked by Martesia during entire exposure or as of 15 August 1963.

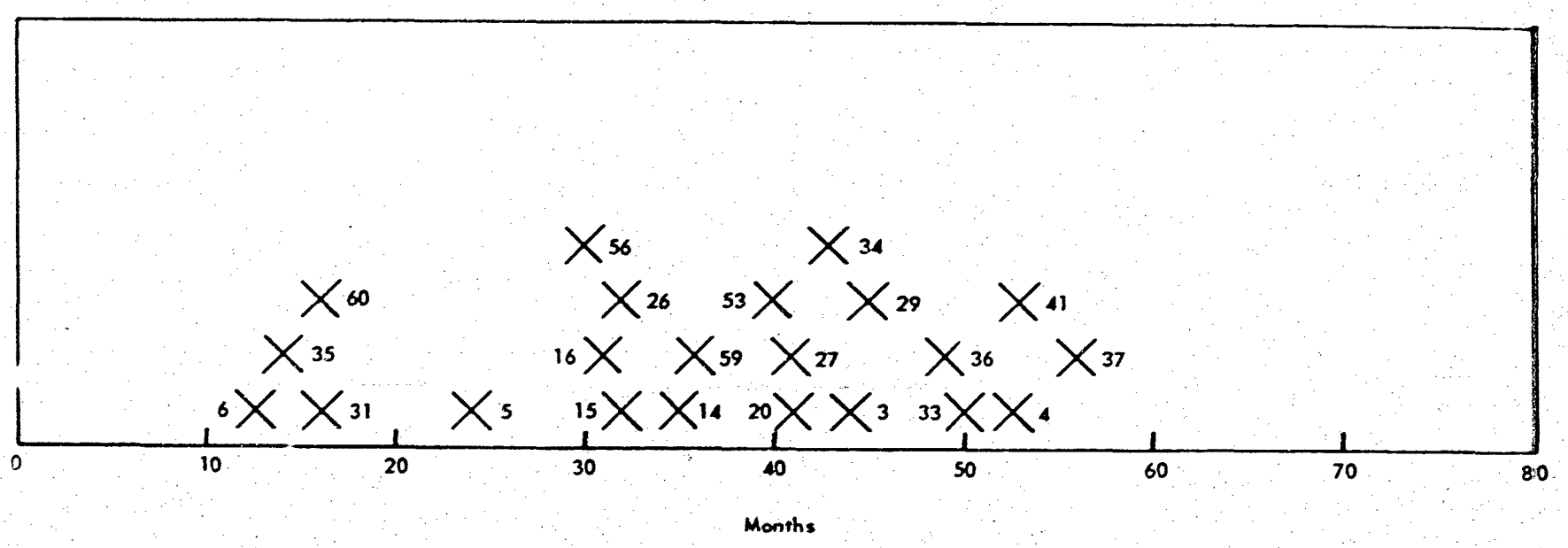

Figure 5. Pearl Harbor panels not attacked by teredine borers during entire exposure.